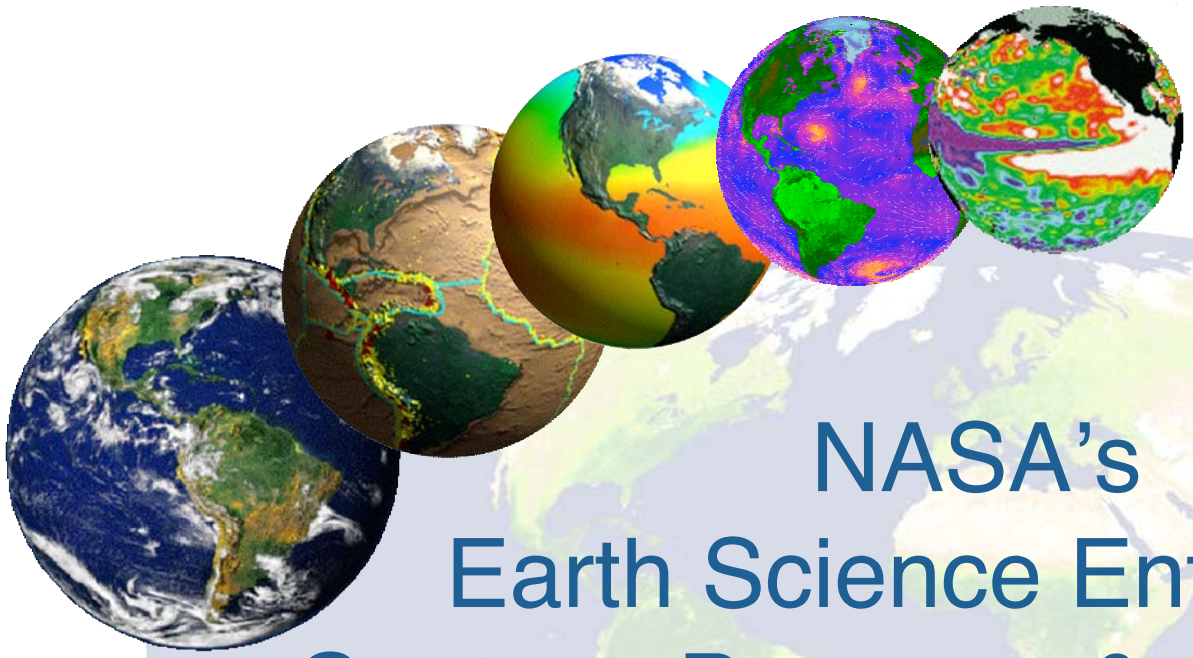


NASA's Earth Science Enterprise Context, Progress & Challenges

ESSAAC XVI
July 16, 2003


The NASA Vision
To improve life here,
To extend life to there,
To find life beyond.
The NASA Mission
To understand and protect our home planet,
To explore the universe and search for life,
To inspire the next generation of explorers
... as only NASA can.

Agency Goals

Mission-Driven Goals

Understand and protect our home planet	1.	**Understand the Earth system and apply Earth system science to improve prediction of climate, weather, and natural hazards.**
	2.	**Enable a safer, more secure, efficient, and environmentally friendly air transportation system.**
	3.	**Create a more secure world and improve the quality of life by investing in technologies and collaborating with other agencies, industry, and academia.**
Explore the Universe and search for life	4.	**Explore the fundamental principles of physics, chemistry, and biology through research in the unique natural laboratory of space.**
	5.	**Explore the solar system and the universe beyond, understand the origin and evolution of life, and search for evidence of life elsewhere.**
Inspire the next generation of explorers	6.	**Inspire and motivate students to pursue careers in science, technology, engineering, and mathematics.**
	7.	**Engage the public in shaping and sharing the experience of exploration and discovery.**

Enabling Goals

	8.	**Ensure the provision of space access for the nation, and improve it through increased safety, reliability and affordability.**
	9.	**Extend the duration and boundaries of human space flight to create new opportunities for exploration and discovery.**
	10.	**Enable revolutionary capabilities through new technology.**

Agency Themes

SPACE SCIENCE
- Solar System Exploration (SSE)
- Mars Exploration (MEP)
- Astronomical Search for Origins (ASO)
- Structure and Evolution of the Universe (SEU)
- Sun-Earth Connections(SEC)

EARTH SCIENCE
- Earth System Science (ESS)
- Earth Science Applications (ESA)

BIOLOGICAL AND PHYSICAL RESEARCH
- Biological Sciences Research (BSR)
- Physical Sciences Research (PSR)
- Research Partnerships and Flight Support (RPFS)

AERONAUTICS AND SPACE TECHNOLOGY
- Aeronautics Technology (AT)
- Space Launch Initiative (SLI)
- Mission and Science Measurement Technology (MSM)
- Innovative Technology Transfer Partnerships (ITTP)

EDUCATION PROGRAMS
- Education Programs (EDUC)

SPACE FLIGHT
- Space Station (ISS)
- Space Shuttle (SSP)
- Space and Flight Support (SFS)

Near Term: Return to Flight (RTF) Process

Return to Flight

Program Implementation

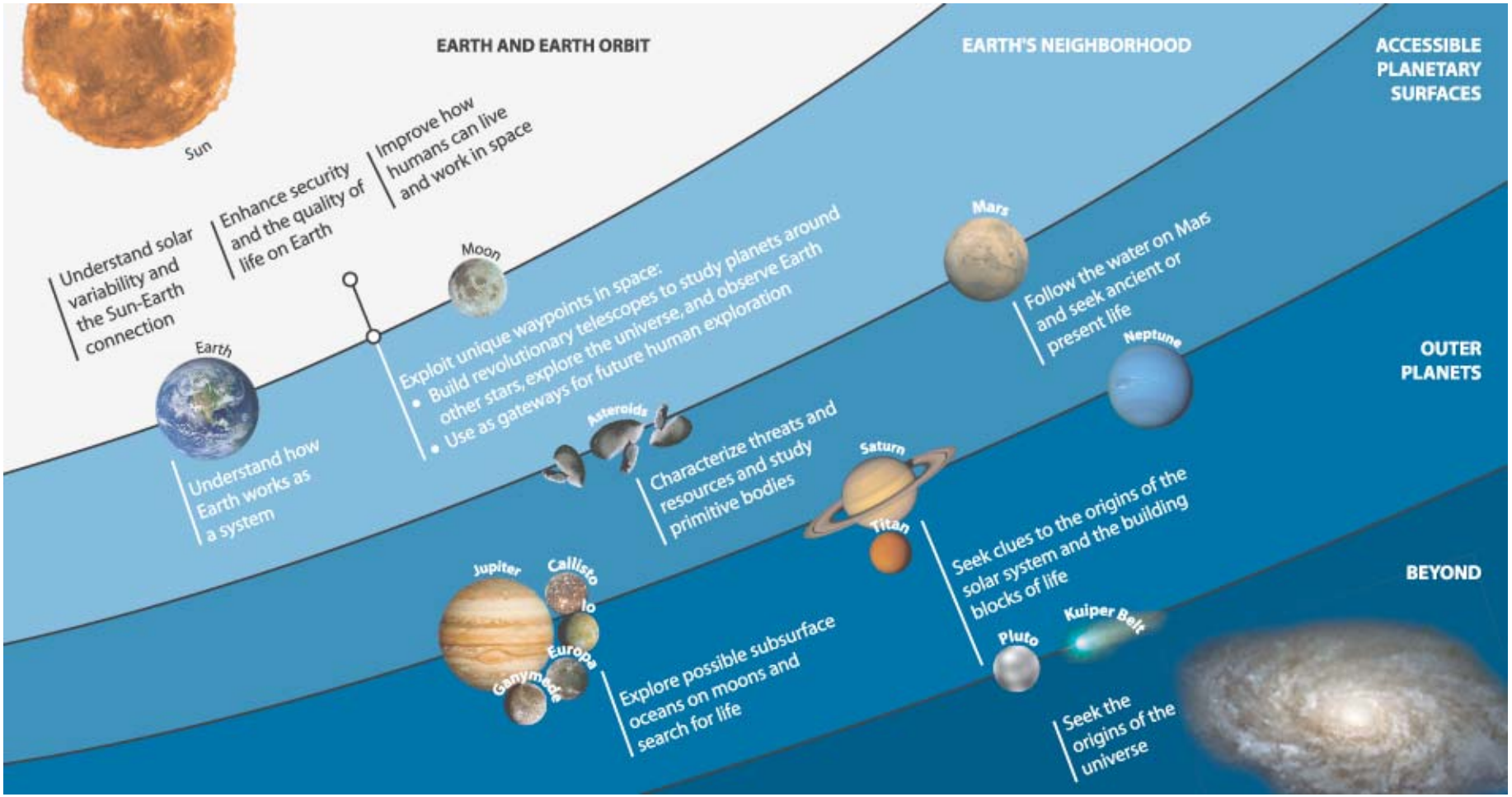
Space Flight Leadership Council Approval

PRCB Review and Recommended Approval By Co-Chairs

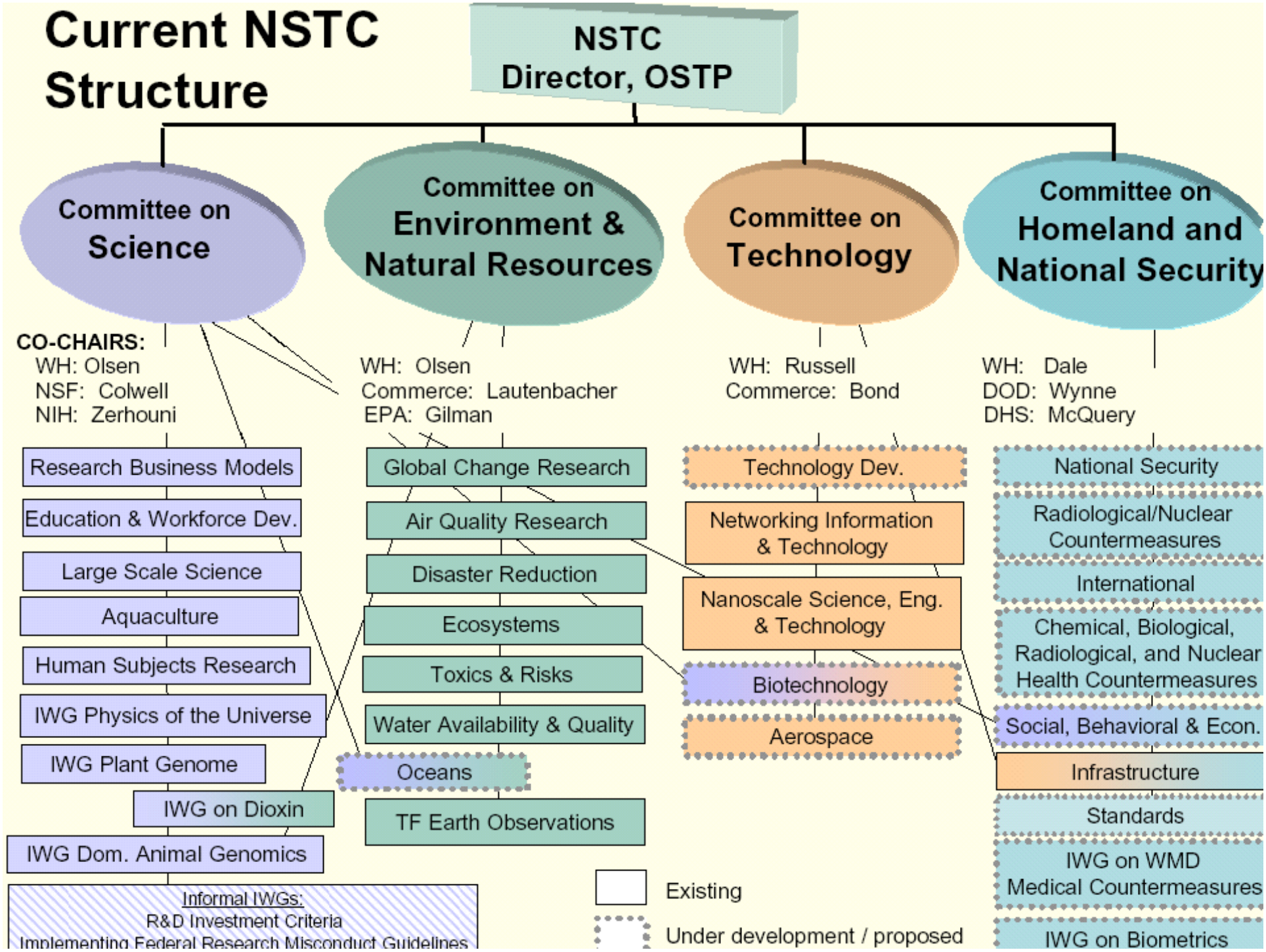
RTF Planning Team Meetings

CAIB Recommendations and Shuttle Project RTF Redesigns & Process Changes

Long Term: A Space Architecture to Implement the NASA Mission

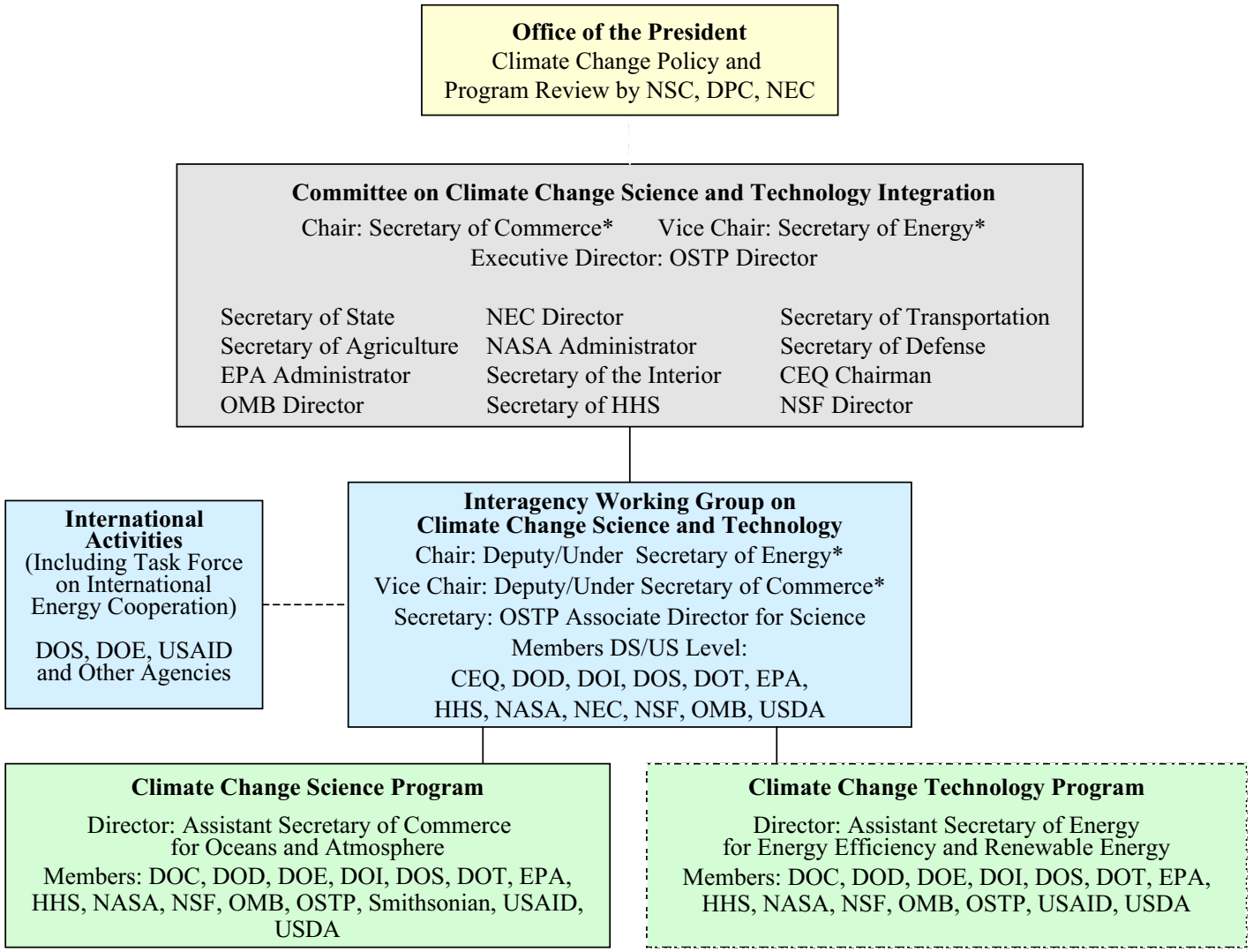


ESE has the lead for the "understand and protect" piece.


Current NSTC Structure
NSTC Director, OSTP
Committee on Science
Committee on Environment & Natural Resources
Committee on Technology
Committee on Homeland and National Security
CO-CHAIRS:
WH: Olsen
NSF: Colwell
NIH: Zerhouni
WH: Olsen
Commerce: Lautenbacher
EPA: Gilman
WH: Russell
Commerce: Bond
WH: Dale
DOD: Wynne
DHS: McQuery
Research Business Models
Education & Workforce Dev.
Large Scale Science
Aquaculture
Human Subjects Research
IWG Physics of the Universe
IWG Plant Genome
IWG on Dioxin
IWG Dom. Animal Genomics
Global Change Research
Air Quality Research
Disaster Reduction
Ecosystems
Toxics & Risks
Water Availability & Quality
Oceans
TF Earth Observations
Technology Dev.
Networking Information & Technology
Nanoscale Science, Eng. & Technology
Biotechnology
Aerospace
National Security
Radiological/Nuclear Countermeasures
International
Chemical, Biological, Radiological, and Nuclear Health Countermeasures
Social, Behavioral & Econ.
Infrastructure
Standards
IWG on WMD Medical Countermeasures
IWG on Biometrics
Informal IWGs:
R&D Investment Criteria
Implementing Federal Research Misconduct Guidelines
Existing
Under development / proposed

Managing Federal Climate Change Research & Technology

Climate Science and Technology Management Structure



*Chair and Vice Chair of Committee and Working Group rotate annually

November 2002

NASA / CCSP Alignment

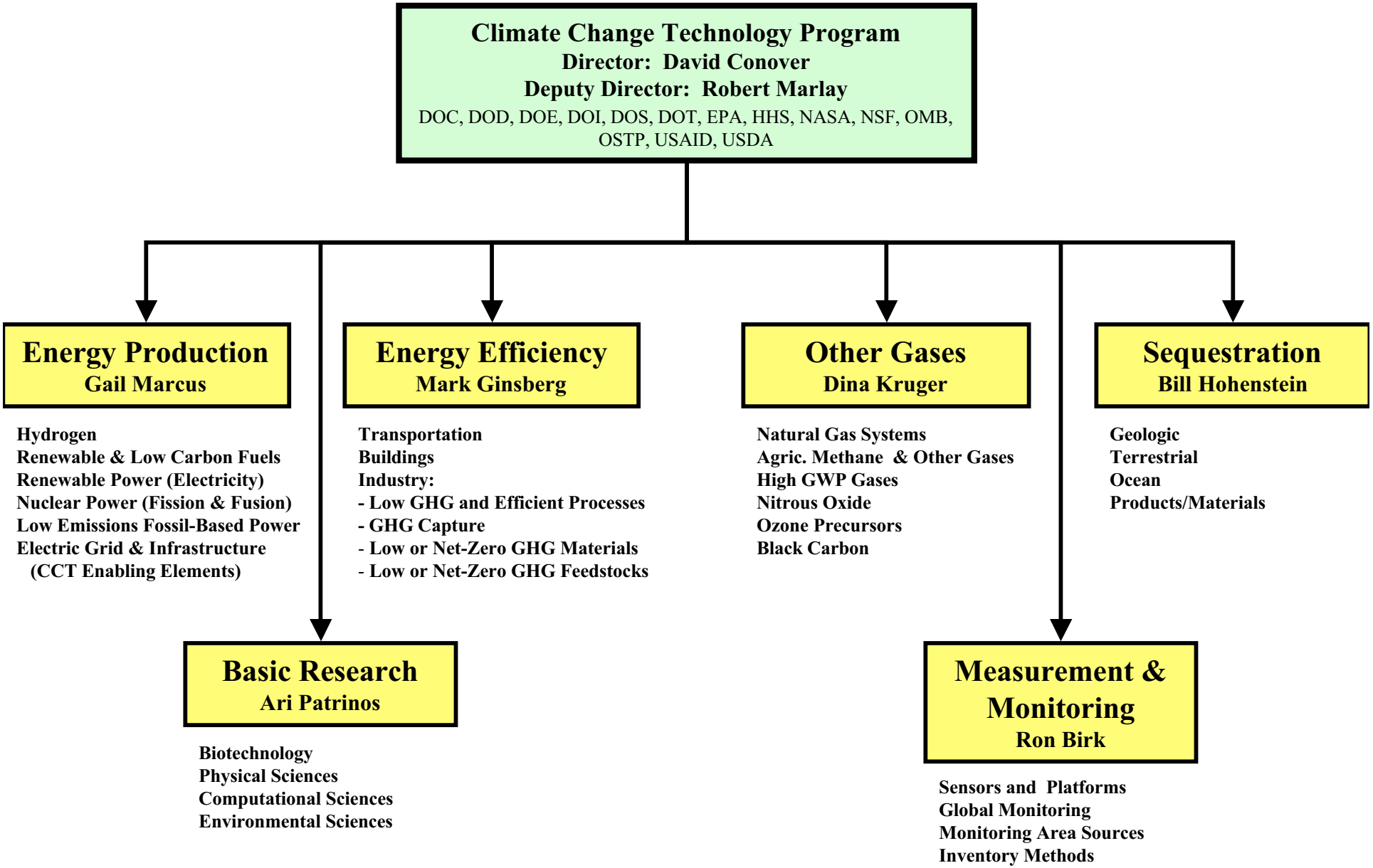
NASA Science Focus Areas

- Climate Variability & Change
- Atmospheric Composition
- Carbon Cycle & Ecosystems
- Water & Energy Cycle
- Weather
- Earth Surface & Interior

CCSP Research Elements

- Climate Variability & Change
- Atmospheric Composition
- Global Carbon Cycle
- Land Use / Land Cover Change
- Ecosystems
- Global Water Cycle
- Human Contributions & Responses

CCTP Working Groups and Subgroups

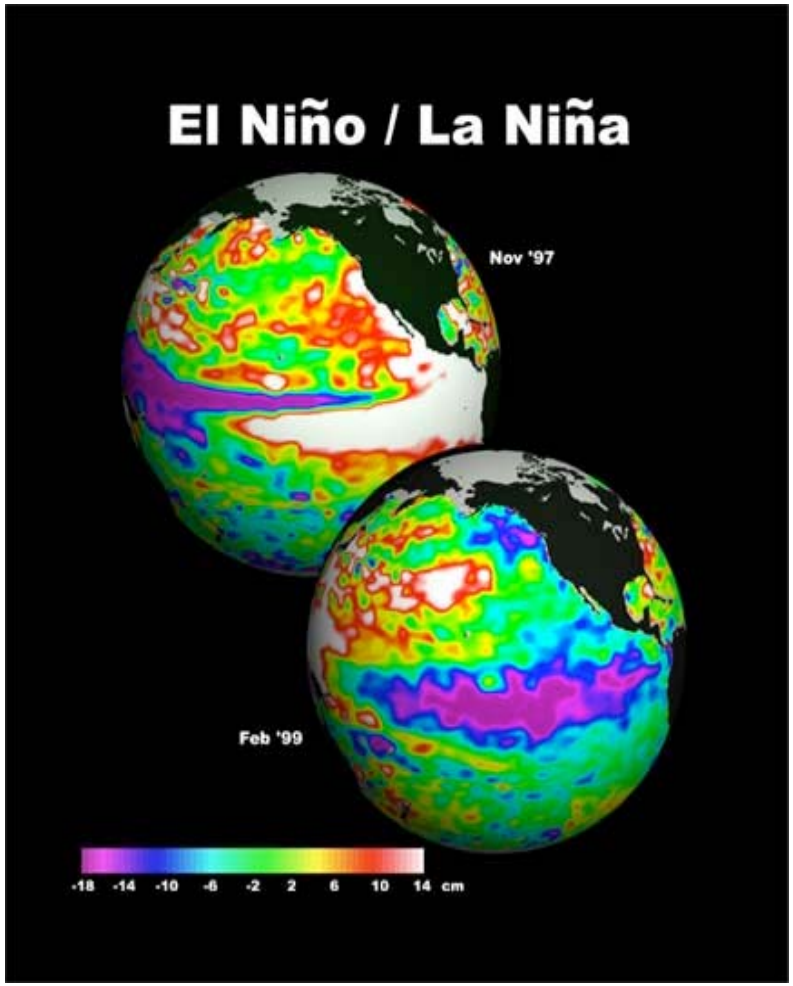


Earth Science in the NASA Mission

- *Leading* role in understanding and protecting our home planet
- *Supporting* role in exploring the universe
- *Essential* role in inspiring the next generation

NASA's Leadership in Earth System Science

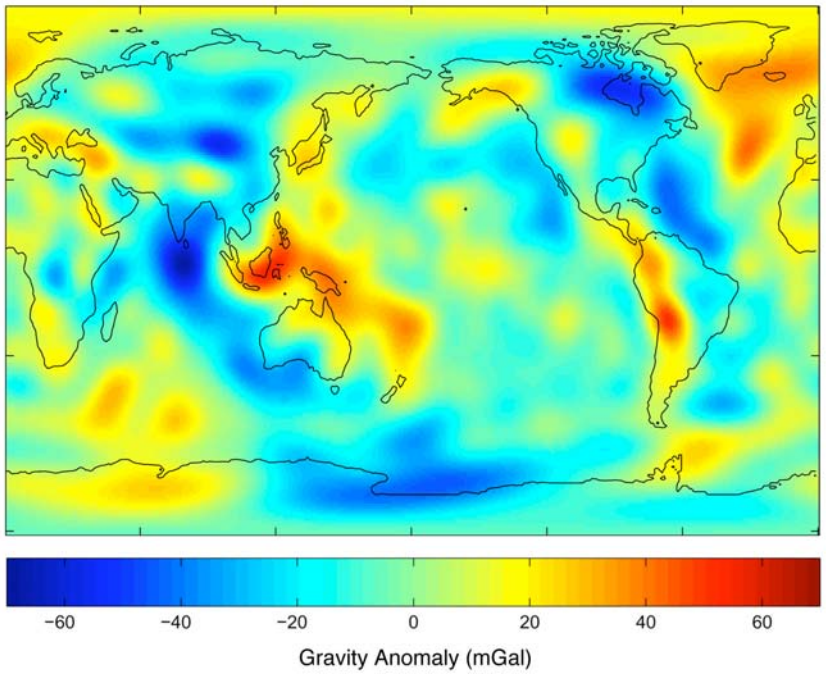
- Measuring and monitoring continental drift and plate tectonics, and understanding their impact on natural hazards, earthquakes and volcanoes
- Capturing and documenting dynamics of Earth's Ozone layer and understanding the impacts of its depletion on human exposure to UV radiation
- Capturing and documenting global ocean circulation and its role in Earth's weather and climate
- Capturing the seasonal dynamics of land vegetation and ocean phytoplankton, and their capacity to cycle carbon through the Earth system and in food and fiber production
- Mapping the 3-D structure of storms and hurricanes and their impacts on human safety, property, and infrastructure



NASA's Leadership in Earth System Science

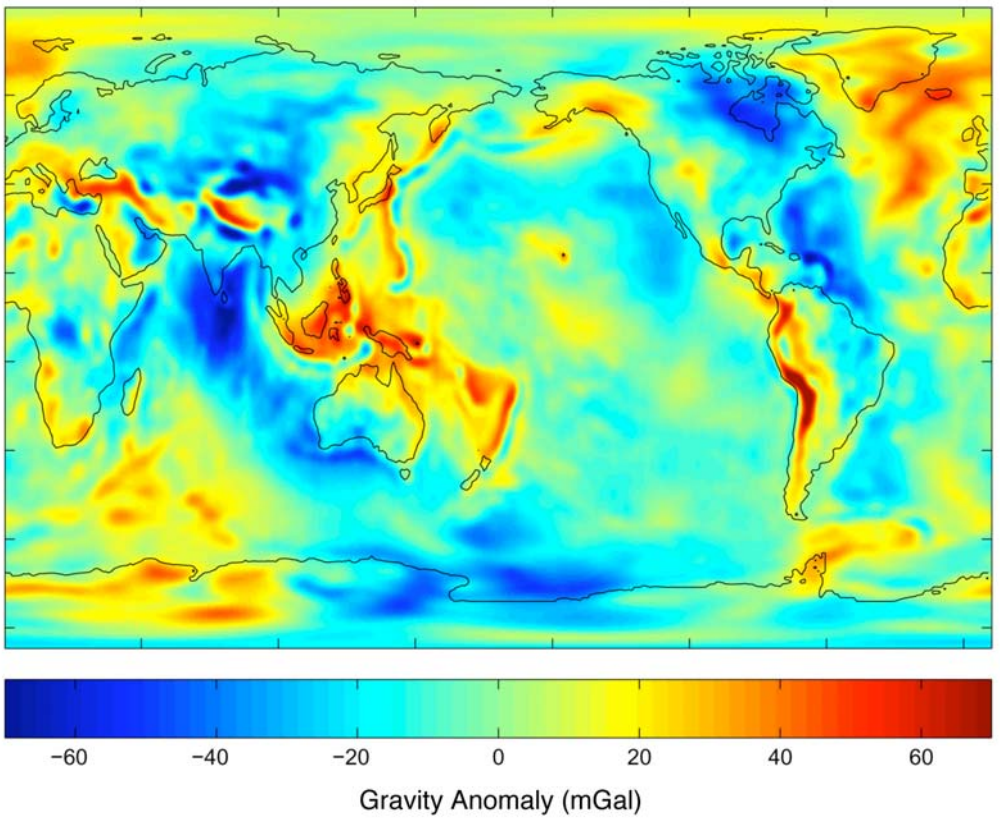
- Mapping Greenland and Antarctica in 3-D with unprecedented accuracy to understand their role in Earth's weather, climate and sea level change
- Measuring the Earth's Radiation budget and its variations with unprecedented accuracy to assess its impacts on Earth's climate and weather
- Measuring Earth's gravity field and its variations over time with unprecedented accuracy to assess its impacts on ocean circulation and Earth's climate
- Measuring the distribution of aerosols and clouds and assessing their roles in Earth's climate and energy budget
- Mapping the Earth's surface in 3D with unprecedented accuracy and resolution and using this knowledge to improve understanding of floods, earthquakes & volcanoes

Measuring Gravity from Space



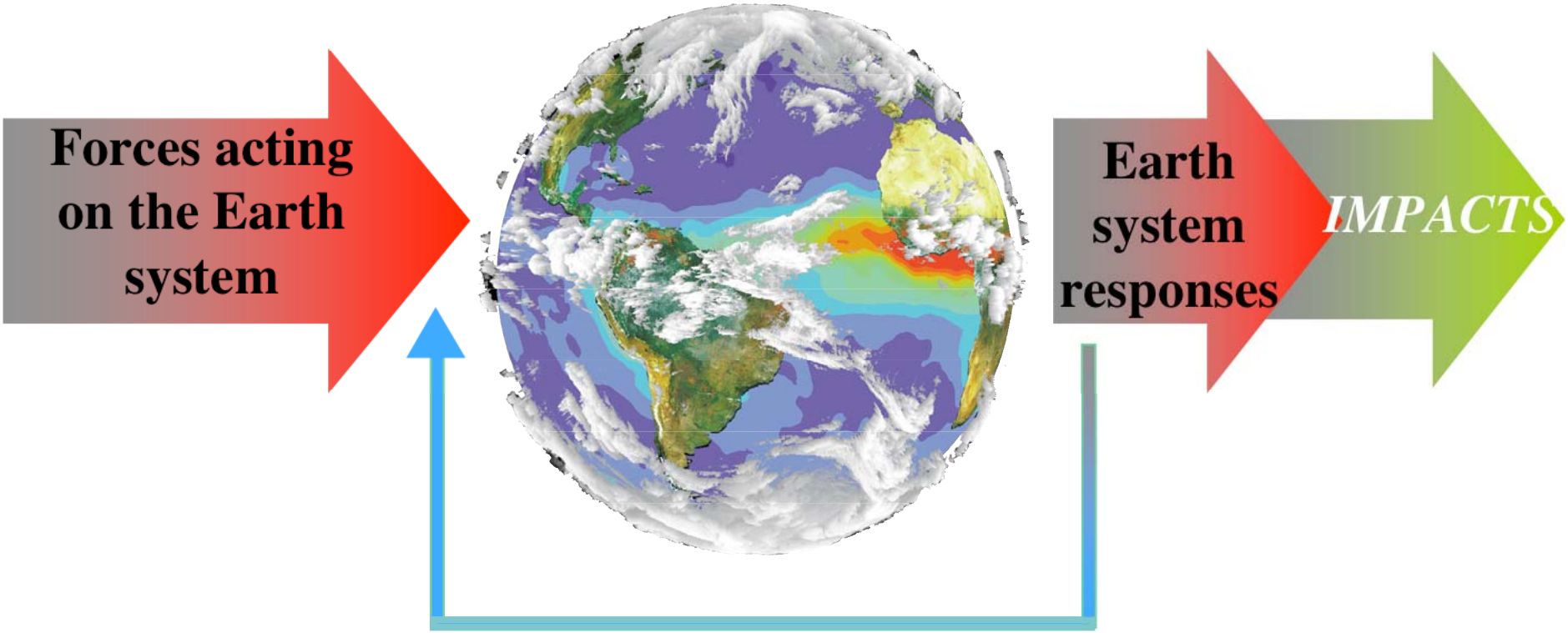
From decades of tracking geodetic satellites

From 111 days of GRACE data



* at ~300 km resolution

Earth is a Complex & Dynamic System



Of the total forcing of the climate system, 40% is due to the direct effect of greenhouse gases and aerosols, and 60% is from feedback effects, such as increasing concentrations of water vapor as temperature rises.

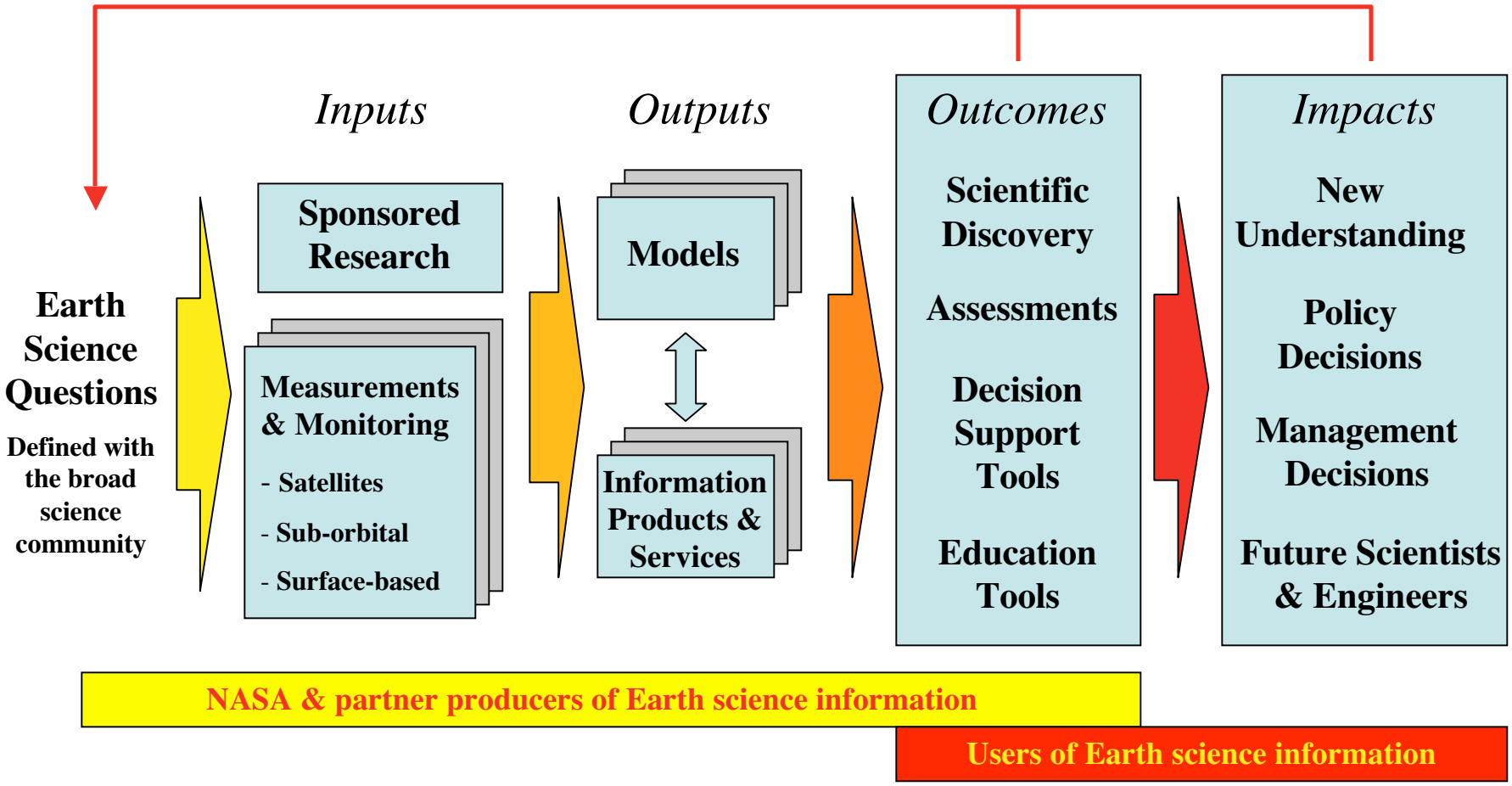
Doing ESS as Only NASA Can

- **NASA pursues frontier science questions of societal importance where remote sensing can make a defining contribution**

- **We seek answers to science questions via an end-to-end approach of basic research, observations, modeling & analysis and technology development, along with our partners**

- **Where other agencies have scientific leadership (e.g., NSF in human dimensions of global change), we support where our observations and products can help**

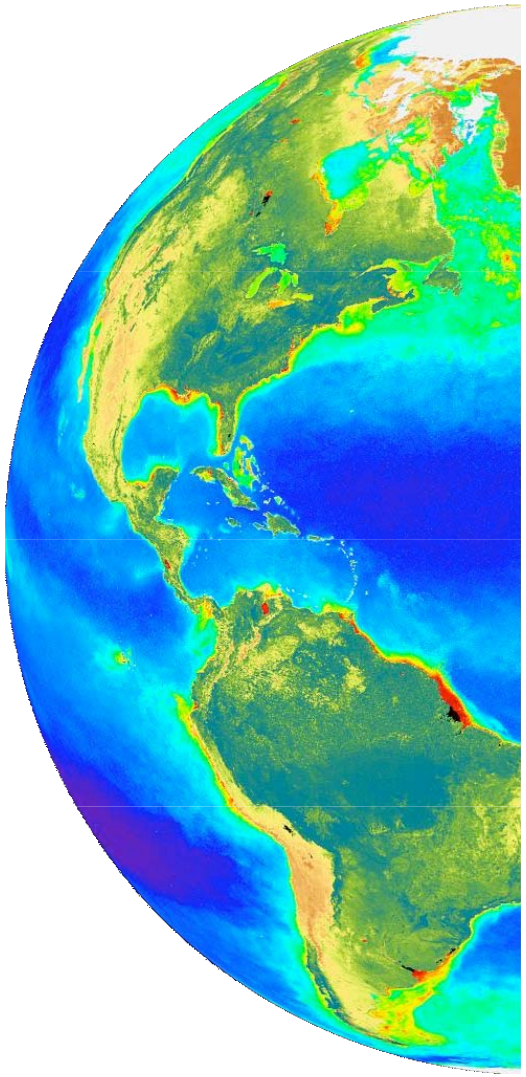
From Science to Societal Impact (& Back Again)

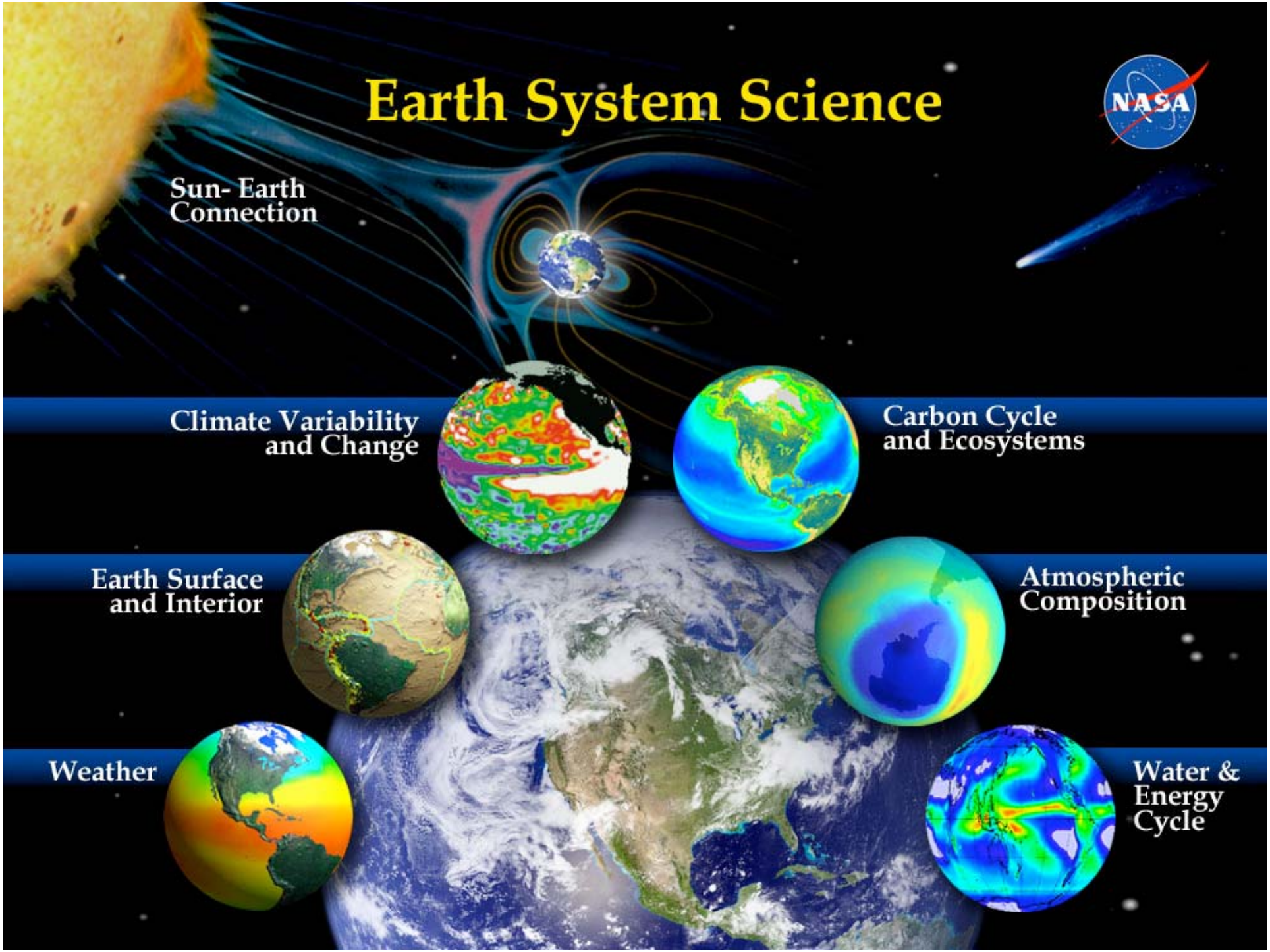


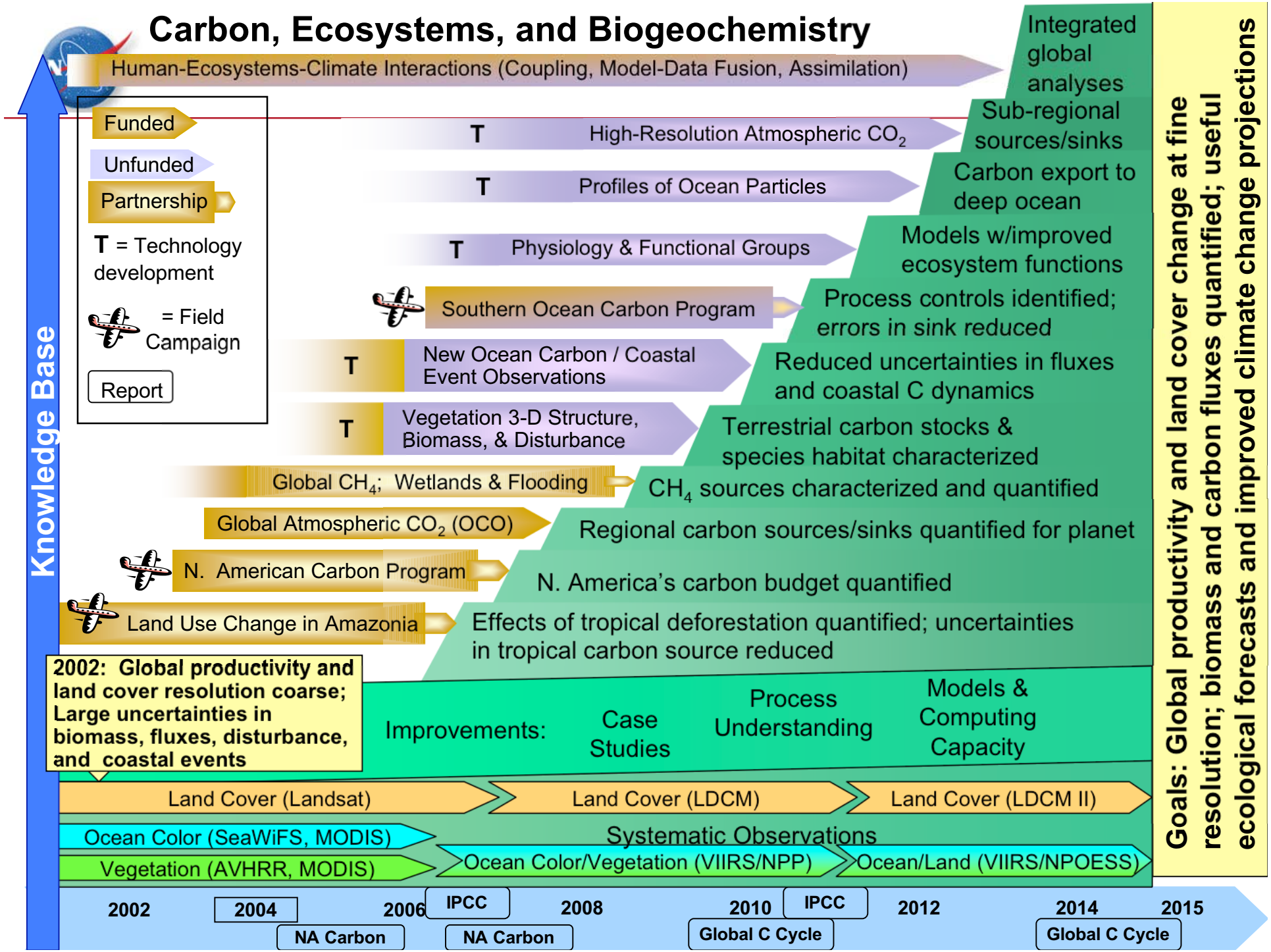
Fundamental Science Questions

How is the Earth changing and what are the consequences of life on Earth?

- How is the global Earth system *changing*?
- What are the primary *forcings* of the Earth system?
- How does the Earth system *respond* to natural and human-induced changes?
- What are the *consequences* of changes in the Earth system for human civilization?
- How well can we *predict* future changes in the Earth system?




Earth System Science
NASA
Sun- Earth Connection
Climate Variability and Change
Carbon Cycle and Ecosystems
Earth Surface and Interior
Atmospheric Composition
Weather
Water & Energy Cycle


Carbon, Ecosystems, and Biogeochemistry
Human-Ecosystems-Climate Interactions (Coupling, Model-Data Fusion, Assimilation)
Integrated global analyses
Funded
Unfunded
Partnership
T = Technology development
= Field Campaign
Report
T
High-Resolution Atmospheric CO_2
Sub-regional sources/sinks
T
Profiles of Ocean Particles
Carbon export to deep ocean
T
Physiology & Functional Groups
Models w/improved ecosystem functions
Southern Ocean Carbon Program
Process controls identified; errors in sink reduced
T
New Ocean Carbon / Coastal Event Observations
Reduced uncertainties in fluxes and coastal C dynamics
T
Vegetation 3-D Structure, Biomass, & Disturbance
Terrestrial carbon stocks & species habitat characterized
Global CH_4; Wetlands & Flooding
CH_4 sources characterized and quantified
Global Atmospheric CO_2 (OCO)
Regional carbon sources/sinks quantified for planet
N. American Carbon Program
N. America's carbon budget quantified
Land Use Change in Amazonia
Effects of tropical deforestation quantified; uncertainties in tropical carbon source reduced
Knowledge Base
2002: Global productivity and land cover resolution coarse; Large uncertainties in biomass, fluxes, disturbance, and coastal events
Improvements:
Case Studies
Process Understanding
Models & Computing Capacity
Land Cover (Landsat)
Land Cover (LDCM)
Land Cover (LDCM II)
Ocean Color (SeaWiFS, MODIS)
Systematic Observations
Vegetation (AVHRR, MODIS)
Ocean Color/Vegetation (VIIRS/NPP)
Ocean/Land (VIIRS/NPOESS)
Goals: Global productivity and land cover change at fine resolution; biomass and carbon fluxes quantified; useful ecological forecasts and improved climate change projections
2002
2004
2006
IPCC
2008
2010
IPCC
2012
2014
2015
NA Carbon
NA Carbon
Global C Cycle
Global C Cycle

Research

- Progress:
  - Defined the questions appropriate for NASA and implementation roadmaps to answer them
  - Moving to identify the climate data records for which we should take responsibility
    - Moving from mission science teams to measurement-focused teams that span generations of satellite missions
  - Investing in data assimilation and modeling to enable the use of new data types to improve predictions and process understanding
- Challenges:
  - Continued & expanded community involvement is essential
  - End-to-end management
  - Competition vs stability

NASA's Earth Observing System

& Related Satellites

Earth Observing System

Candidate Future Missions
In Formulation /Preformulation


Terra

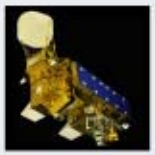

Landsat

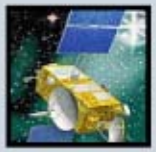

ICESat


Calipso


EO-3: GIFTS

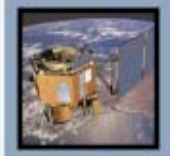

NOAA/GOES


Aqua


Jason


SeaWiFS


Cloudsat

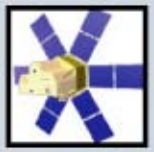

EO-1: ALI
& Hyperion

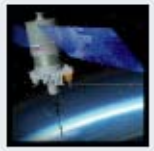

NOAA/POES


SeaWinds
(QuikSCAT, ADEOS II)


GRACE


Aura


SORCE, ACRIM


SAGE III


TRMM

The Earth Observing System -- systematic measurement of interactions among land, oceans, atmosphere, ice & life

Exploratory missions to probe key Earth system processes globally for the first time

Operational precursor/ Technology demos

Operational weather services missions for NOAA

Next Generation Missions

Next Generation Missions

Candidate Future Missions
In Formulation /Preformulation

NPOESS Preparatory Project

Ocean Vector Winds Mission

Synthetic Aperture Radar

Orbiting Carbon Observatory

Advanced Gravity

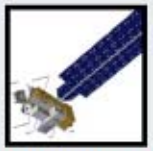
Ocean Carbon

Cold Climate Processes

Vegetation Recovery

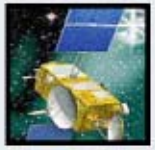
Landsat Data Continuity Mission

Global Precipitation Measurement

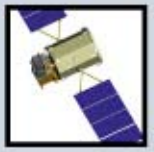


Chemistry/Climate Mission

Aquarius

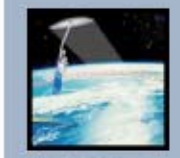


Ocean Surface Topography Mission



Aerosol Polarimeter Sensor

Cryosphere Monitoring Mission



Hydros

Next generation systematic measurement missions to extend/enhance the record of science-quality global change data

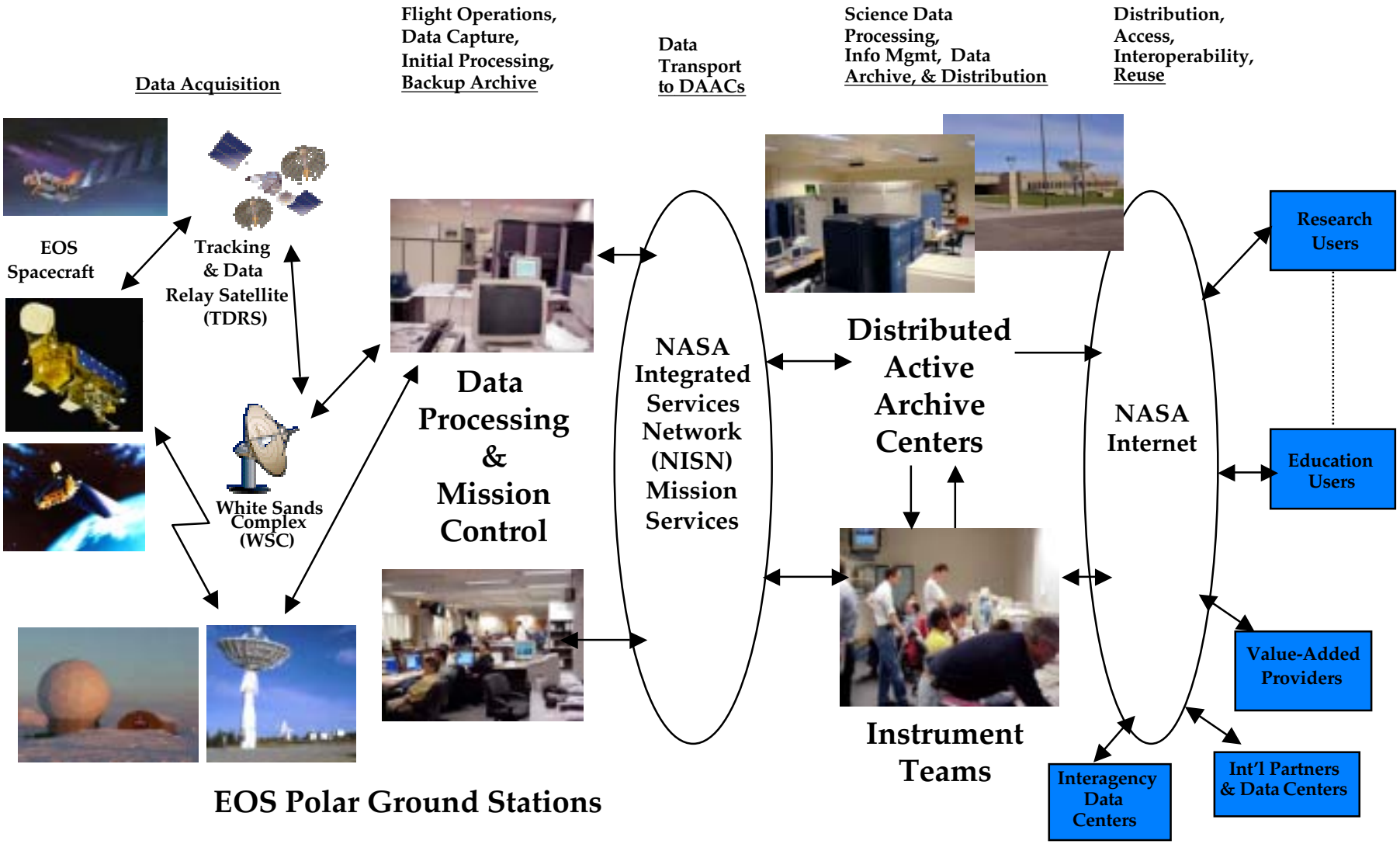
Research missions to probe key Earth system processes globally for the first time

Future research Measurements

Observing Systems

- Progress:
  - Completing deployment of the first series of EOS
  - Securing the balance of follow-on missions in the FY04-FY05 budget processes
  - Moving from mission data sets to long-term data records
  - Transitioning mature measurements to operational systems
  - Strategy is to add value to those remaining with NASA, e.g., through migration to higher orbits
  - Formation flying of satellites to enhance their scientific productivity
- Challenges:
  - Achieving continuity & calibration across generations of satellites
  - Expanding opportunities for new observing capabilities

EOSDIS Context Diagram



Turning Observations into Information

Petabytes 10^{15}

Multi-platform, multi-parameter, high spatial and temporal resolution, remote & in-situ sensing

Calibration, Transformation To Characterized Geophysical Parameters

Terabytes 10^{12}

Interaction Between Modeling/Forecasting and Observation Systems

Gigabytes 10^{9}

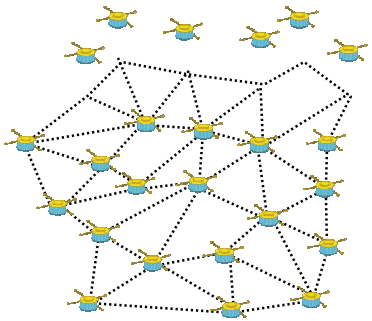
Interactive Dissemination

Predictions

Megabytes 10^{6}

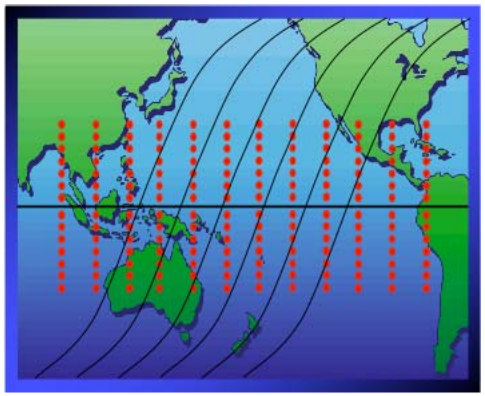
Advanced Sensors

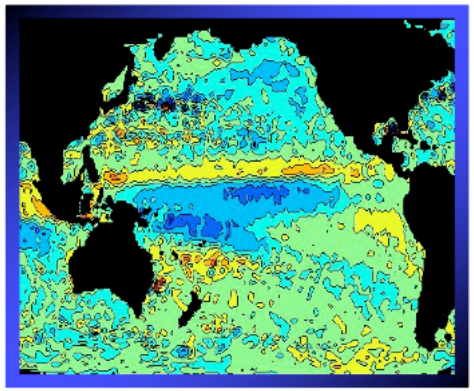
Data Processing & Analysis

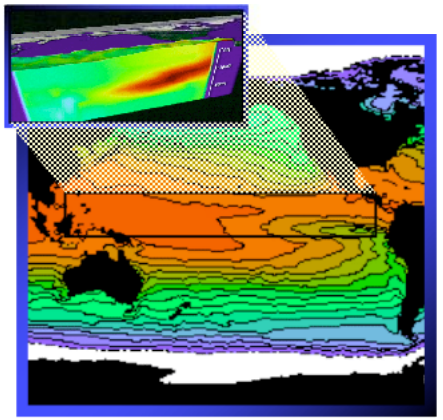


Information Synthesis

Access to Knowledge



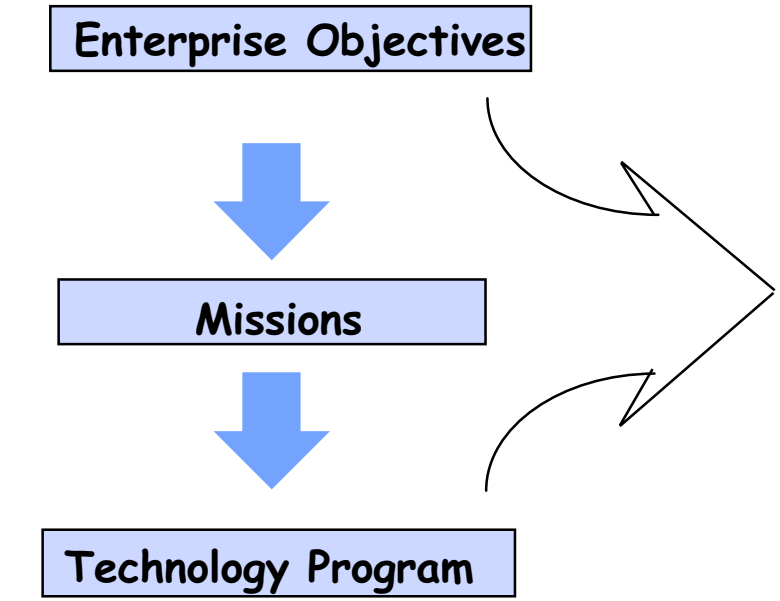




Information Systems

- Progress:
  - Completing EOSDIS--the world's largest "e-science" system for environmental research
  - Selected an EOSDIS Maintenance & Development (EMD) contractor to assure and improve performance of the current system
- Challenges:
  - Identifying the portions of the system that should be evolved as the basis for the next generation capability
  - Must be able to deliver services while evolving the system and adding new technologies

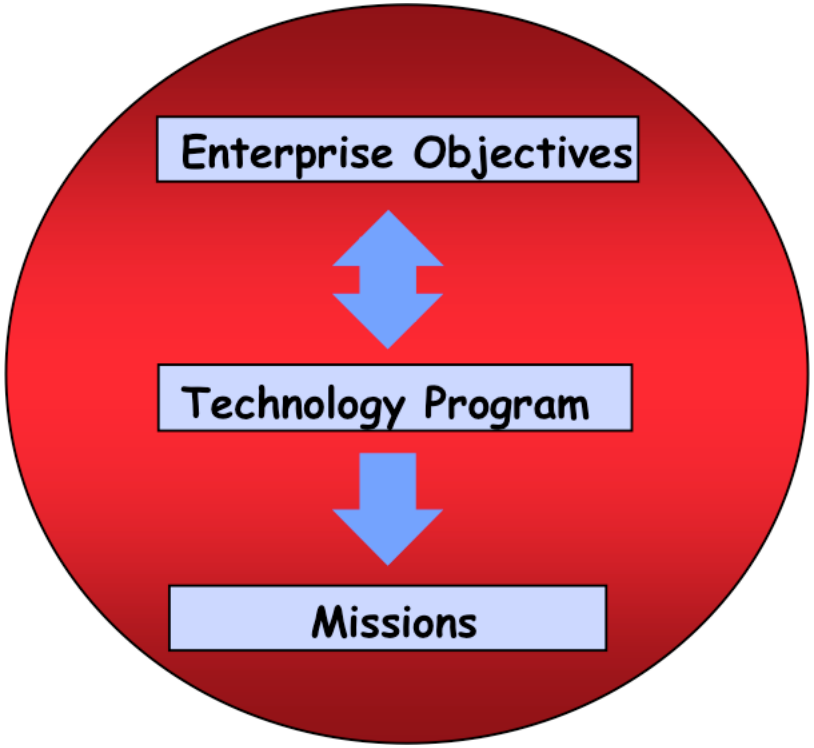
Shift from Technology Derived from Missions to Missions Enabled by Technology



Enterprise objectives established

Missions sets derived from Enterprise objectives

Technology programs derived From mission requirements



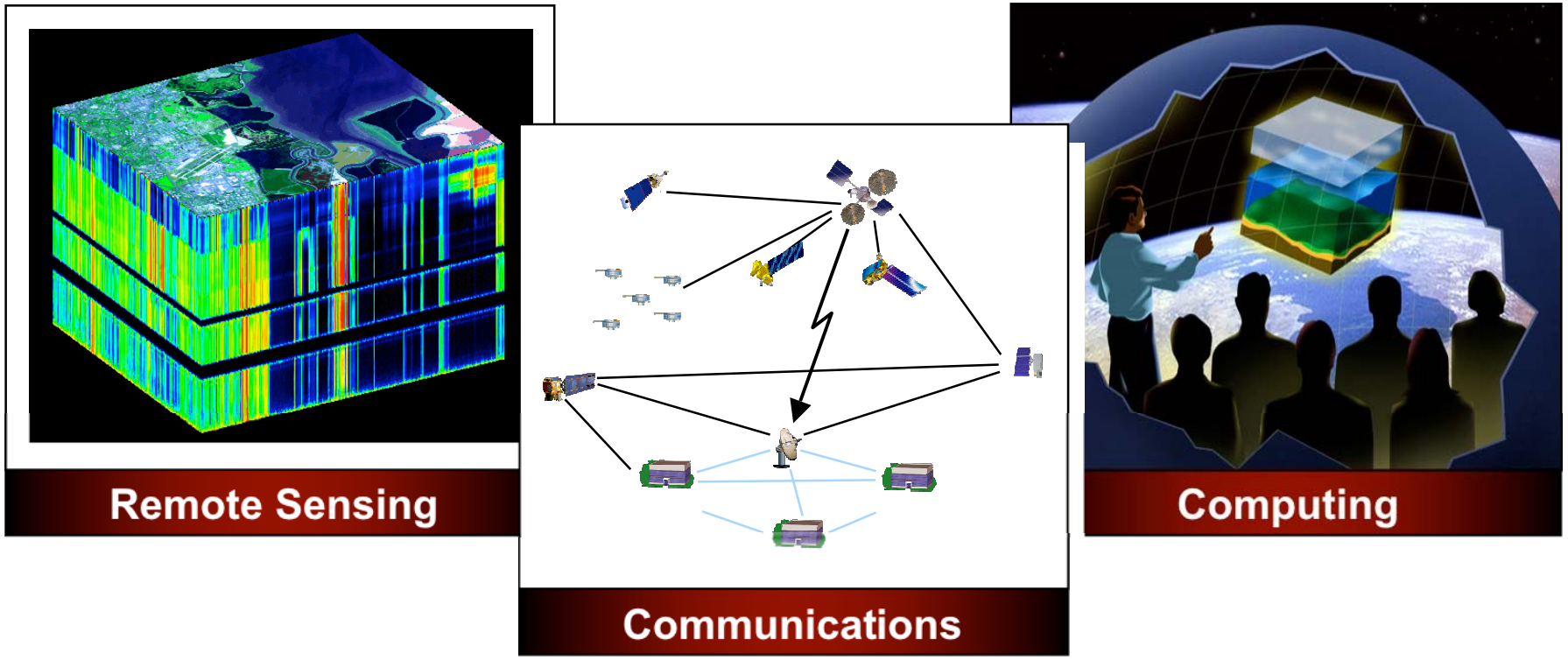
Enterprise objectives drive technology

Technology expands mission horizons

Missions evolve from convergence of objectives and technology

Technology Emphasis Areas

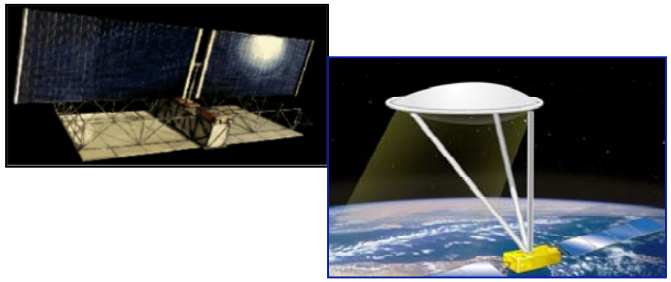
Earth System Science in the future will leverage three ongoing technology revolutions:



...To enable timely and affordable delivery of Earth Science data and information to users

High-Priority, Key Technology Validation Needs for Earth Science

Large Deployable Antennas



Validation enables improved soil moisture and global precipitation science capabilities

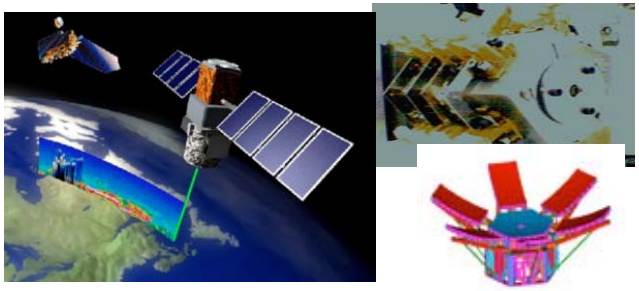
Communications & On-Board Processing

Optical Comm from LEO to GEO

RF Comm demonstrates Ka-band in space

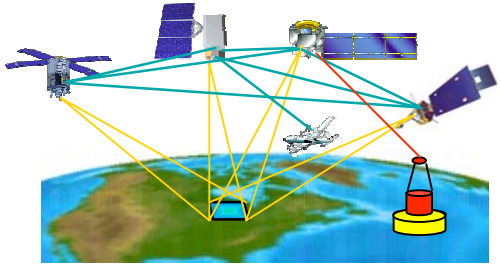
Technology significantly improves spatial/spectral resolution and temporal coverage for science missions

Lasers and Deployable Telescopes



Flight validations enable atmospheric chemistry, aerosols and winds science missions

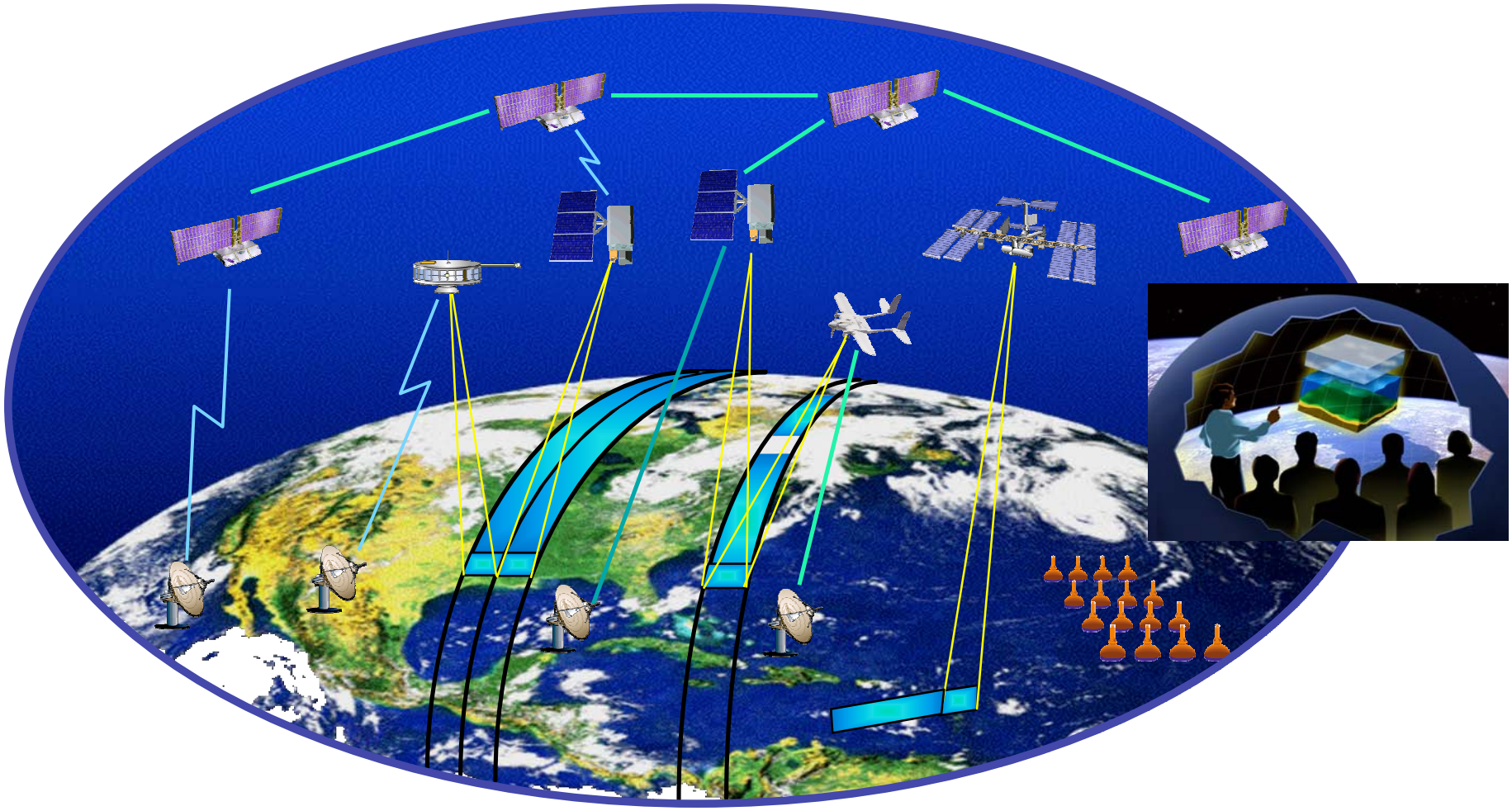
Distributed Platforms



Distributed platforms will lead to "sensor webs" for ocean and atmospheric science missions.

Integrated Observing System of the Future

- **Information Synthesis: Distributed, Reconfigurable, Autonomous**

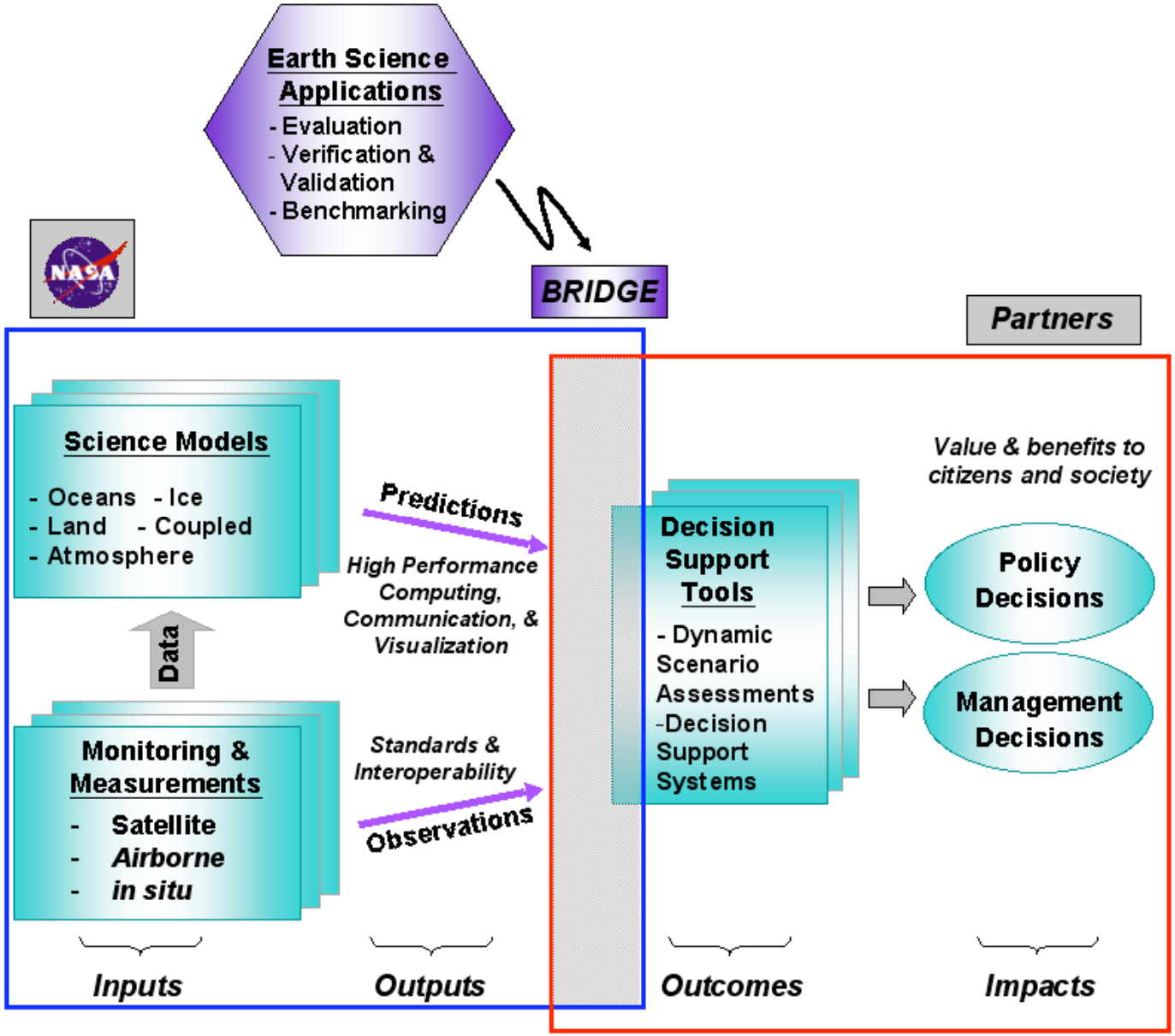


- **Access to Knowledge: On-orbit Processing, Immersive Environments**

Advanced Technology

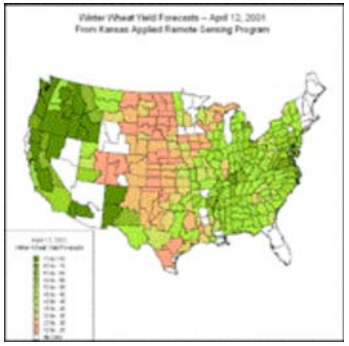
- Progress:
  - Basing technology investments on science requirements
  - Employing competitive solicitations to capture the best ideas
  - Leveraging partnerships with industry and other government laboratories
- Challenges:
  - Balancing mid-term and long-term

Applications: A Systems Approach

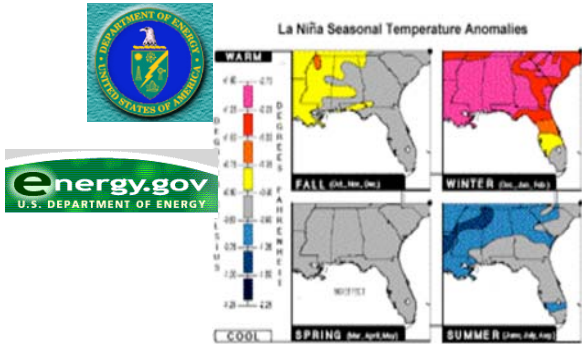


Example National Applications Partnerships

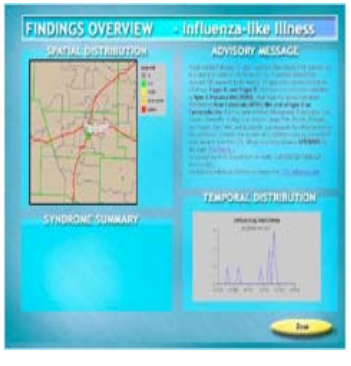
Aviation Safety:
National Airspace System



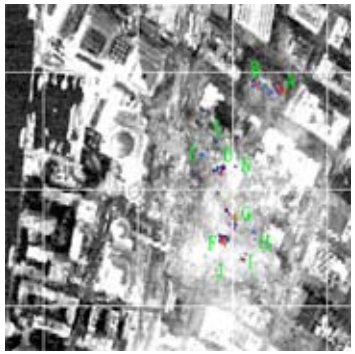
CCRI:
Carbon Management System



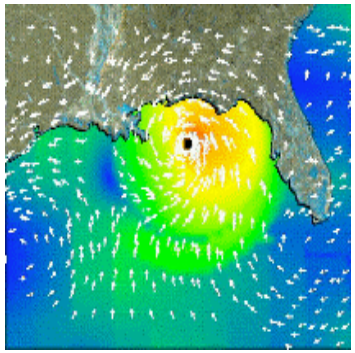
Energy Forecasting:
Renewable Energy System



Public Health:
Risk Assessment System



Homeland Security:
Situation Center



Disaster Preparedness:
HAZUS Risk Prediction

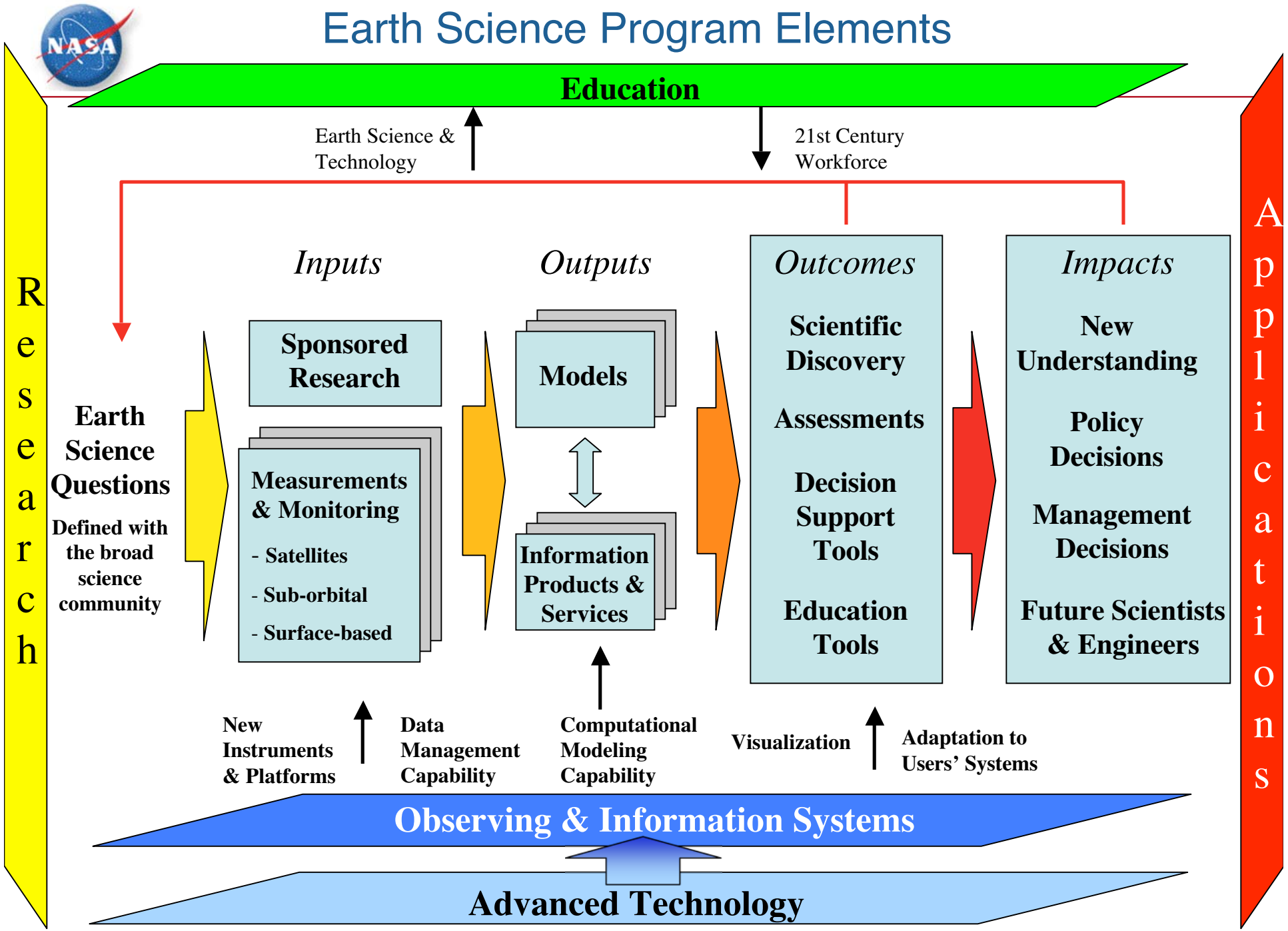
Applications

- Progress:
  - Focusing on a finite set of applications where our sibling agencies assure national impact
  - Identifying specific decision support systems (DSS) owned by these agencies where NASA data and information can help
  - Role of NASA's Applications Program is to "benchmark" (measure the improvement in) DSS performance as a result of adding NASA Earth science information
- Challenges:
  - Working with partner agencies as the develop their information infrastructure to sustain the "pull" of NASA data and information

Education

- Progress:
  - Facilitating the insertion of the Earth System Science concept all along the education "pipeline"
  - Established an Education Product Review process involving professional educators
- Challenges:
  - Aligning the ESE education program with the emerging NASA Education Strategy

Earth Science Program Elements



Summary

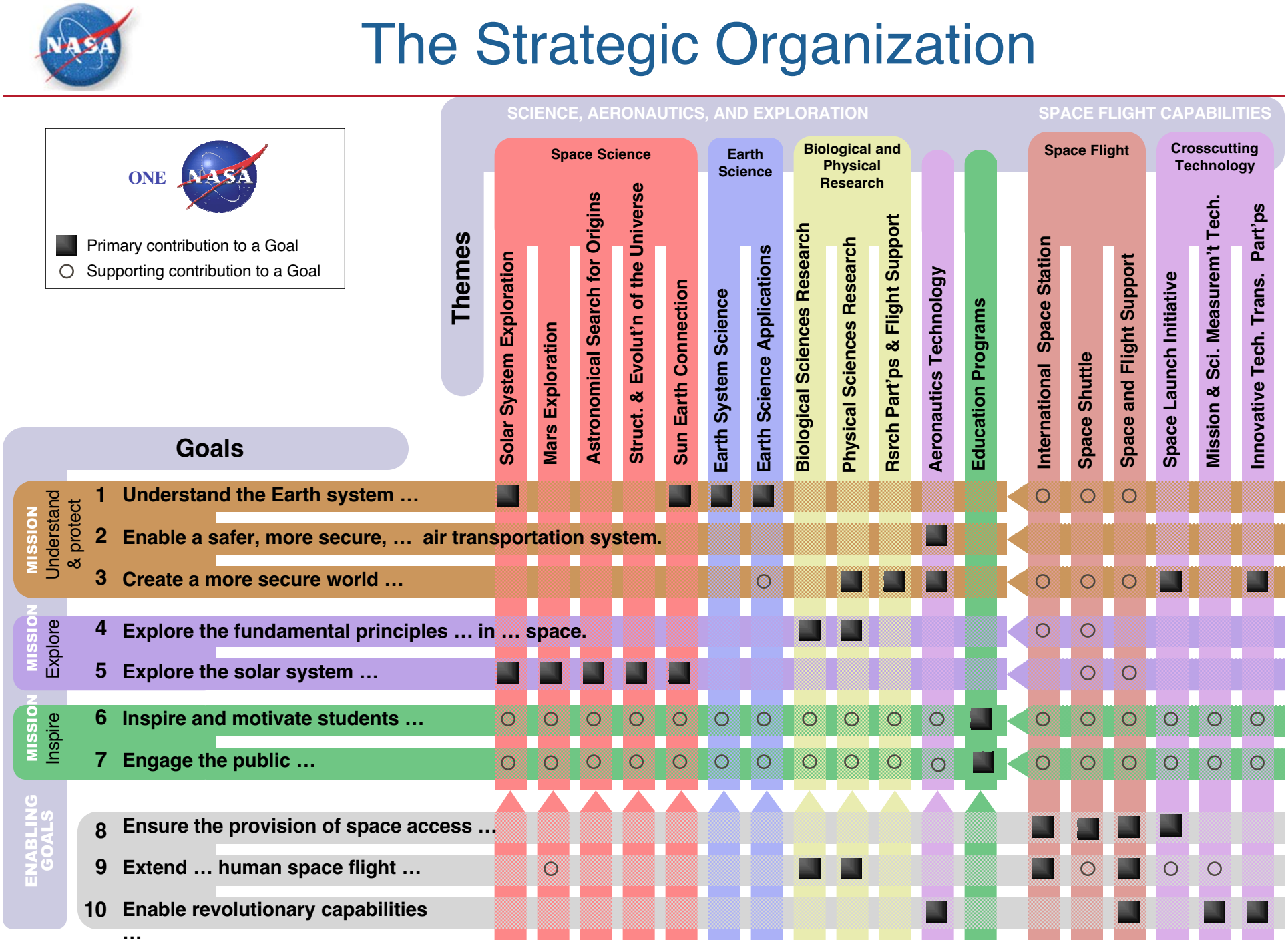
- Balancing the components of a complex program in a complex context!
- At the heart of it all is the Earth System Science concept
- Fulfilling our long-standing commitments, we are now moving to take Earth System Science to the next level
- Investing in areas of our strengths as a research and technology agency
  - Employing the “as only NASA can” filter

How Can ESSAAC Help? Some Ideas:

- Facilitate community participation in implementation planning, e.g., lead planning groups ala SESWG
- Identify high leverage points for NASA on the continuum from science to applications
- Focus the efforts of the Committee and Subcommittees on these challenges
- Others you suggest…

Backup

The Strategic Organization



Charge to the ESISS

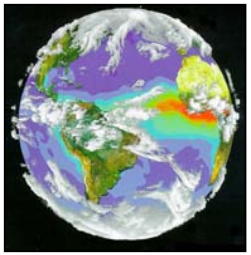
- Absorb the lessons of EOSDIS development
- Approach the new from the standpoint of a commitment by NASA to produce a limited set of climate data records identified in conjunction with the science community
- Help us look ahead to where information technologies will be a decade from now
- Help us to extract the full scientific value of satellites flying in formation, in constellations, and ultimately in sensorwebs

ESE Strategy Documents

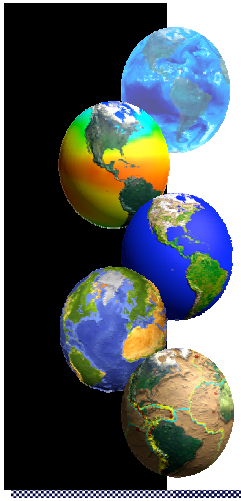
ESE Strategy

ESE Strategy

Research Plan



- *Observing approach*
- *Computational modeling approach*



Technology Plan

Data & Information Management Plan

Applications Plan

Education Plan

NASA / CCSP Alignment

NASA Research Strategy Paradigm

- Variability
- Forcing
- Response
- Consequence
- Prediction

CCSP Goals

- **Improve knowledge of the Earth's past and present climate and environment including its natural variability, and improve understanding to the causes of observed variability and changes**
- **Improve quantification of the forces bringing about changes in the Earth's climate and relate systems**
- **Reduce uncertainties in projections of how Earth's climate and related systems might change in the future**
- **Understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes**
- **Explore the uses and identify the limits of evolving knowledge to manage risk and opportunities related to climate variability and change**

NASA / CCSP Alignment

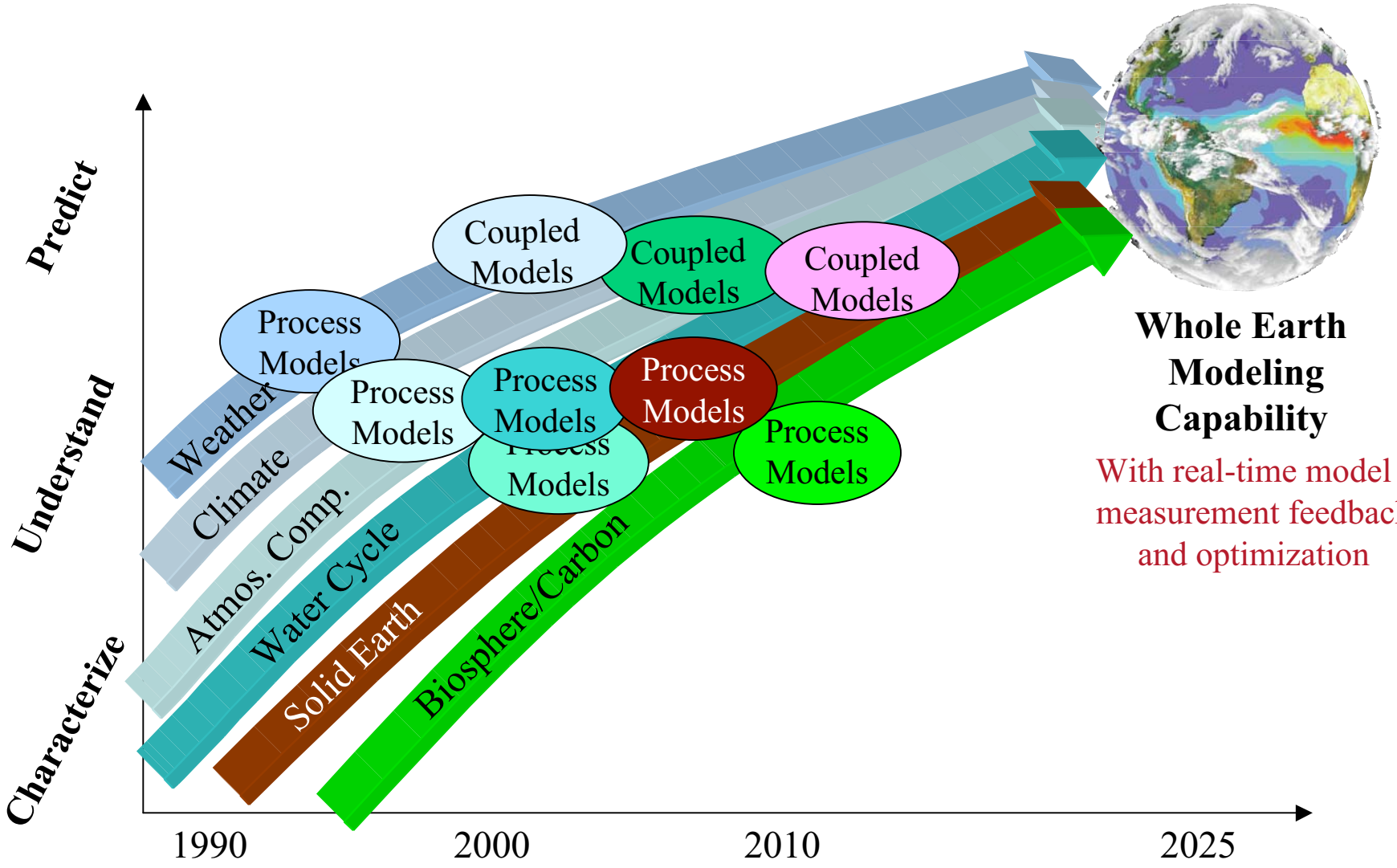
NASA Program Elements

- Research
- Observing & Information Systems
- Applications (for Decision Support)
- Education
- Advanced Technology

CCSP Core Approaches

- Research
- Observations (& Data Management)
- Decision Support
- Communications

Earth System Science Today & Tomorrow: Linking Models That Use Satellite Observations



Modeling at NASA

- What we are doing:
  - Long-term climate modeling
  - Seasonal-to-interannual climate modeling
  - Weather modeling
  - Ocean data assimilation
  - Earthquake and geodynamo simulation
- What we want to do:
  - Single modeling framework for weather and climate
  - Models that utilize new types of NASA data for initialization and evaluation
  - Data assimilation and reanalysis that can uniquely be done by NASA
  - High resolution models that match the resolution of NASA data sets
- What it takes to get there:
  - Hardware- we are currently limited by our computing power and computer architecture
  - Software and system Engineering – putting the SW and HW together
  - Data management and data mining – thinning the vast amount is the key
  - People – computational scientists, system engineering and Earth system modelers work together to achieve enterprise goals

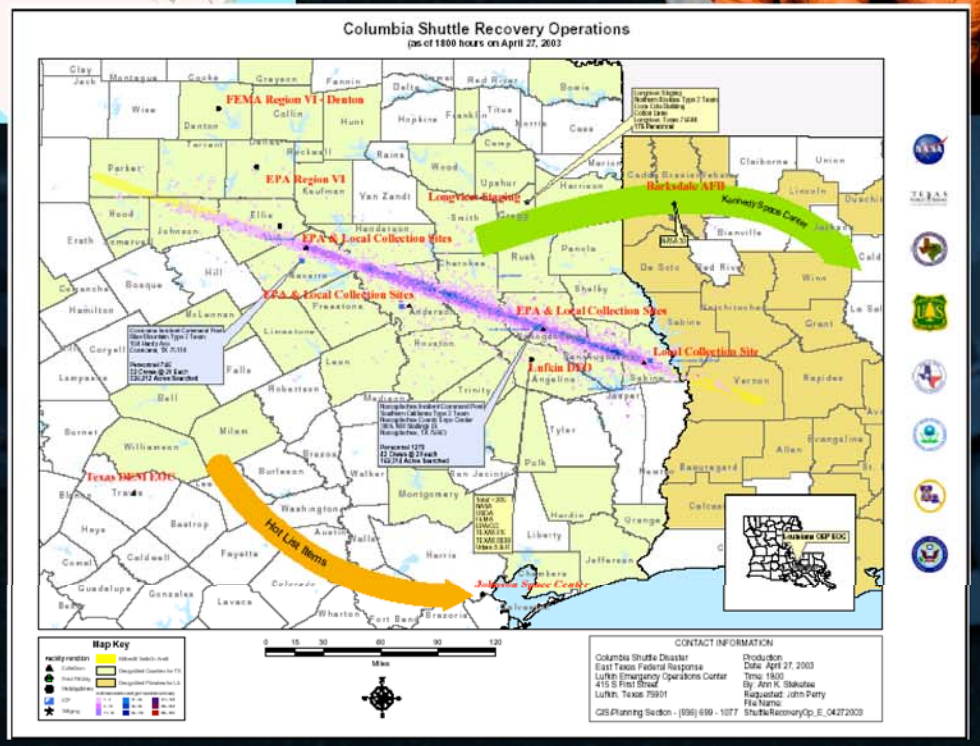
Modeling at NASA – Future strategies

Modeling initiatives that capitalize on NASA's unprecedented new capabilities in space-based Earth observation

- Utilize new type of NASA data for initialization and evaluation of NASA models and to improve predictions
  - ➢ we know our data best
- Create assimilated new data sets for scientific use, including reanalysis when it can uniquely be done by NASA
- Increase resolution of models to match resolution of NASA data
- Create a single modeling environment and strategy for weather and climate predictions

The return on society's investment in space-based observations will come largely from our ability to improve predictions of climate, weather and natural hazards

Columbia Lost on February 1, 2003



Earth System Science